CONTOURED DISC DRIVE HEAD SURFACE AND METHOD

by

Serge J. Fayeulle

Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903

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Related Applications

This application claims priority of United States provisional application Serial Number 60/318,898, filed September 11, 2001.

Field of the Invention

This application relates generally to disc drives and more particularly to a contoured surface of a head in a disc drive to prevent the head from contacting the data portion of the disc surface during use.

Background of the Invention

A disc drive typically includes one or more discs that rotate at a constant high speed during operation of the drive. Information is written to and read from tracks on the discs through the use of an actuator assembly, which rotates during a seek operation. A typical actuator assembly includes a plurality of actuator arms, which extend towards the discs, with one or more flexures extending from each of the actuator arms. Mounted at the distal end of each of the flexures is a head, which acts as an air bearing slider enabling the head to fly in close proximity above the corresponding surface of the associated disc. In contact start/stop drives, each head lands on and takes off from a delimited area of the disc. This area (the park zone) is typically textured in order to limit stiction. The texture is typically comprised of laser-formed bumps, which are typically about 100 Angstroms high. Each head includes contact pads that are designed to contact the park zone during landing and take off. Additionally, some or all of the contact pads are designed to be the first part of the head that will contact the disc surface if the head inadvertently contacts the data portion of the disc during operation. The contact pads thereby prevent other parts of the head, such as the transducer, from being damaged by or causing damage to the disc surface.

Increasing the density of information stored on discs can increase the storage capacity of hard disc drives. To read the densely stored information, designers have decreased the gap fly height between the heads and the discs. Reducing the gap fly height can lead to increased contact between the head and the data portion of the disc, causing unacceptable read/write errors. Accordingly there is a need for an improved head that prevents contact between the head and the

data portion of the disc surface. The present invention provides a solution to this and other problems, and offers other advantages over the prior art.

Summary of the Invention

Against this backdrop the present invention has been developed. One embodiment of the present invention is a method of contouring a surface portion of a head for a disc drive that includes a disc rotatably mounted on a base. The method includes positioning the head over a park zone of the disc and rotating the disc for a selected time to burnish the head against the park zone of the disc while maintaining the head positioned substantially over the park zone.

Another embodiment of the present invention is a disc drive including a rotating disc and an actuator assembly mounted adjacent the disc, the actuator assembly having an actuator arm including a distal end supporting a head over a surface of the disc. The head includes a head surface portion facing the disc surface, wherein the head surface portion has been contoured by positioning the head over a park zone on the disc and maintaining the head positioned substantially over the park zone of the disc while rotating the disc for a selected time so as to burnish the head surface portion.

An embodiment of the present invention may also be summarized as a method of contouring a surface portion of a head for a disc drive. The method includes positioning the head over a park zone of a rotating disc and contouring the head surface portion to reduce contact between the head and the disc during operation of the disc drive.

These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a plan view of a disc drive incorporating a preferred embodiment of the present invention with a portion of the top cover broken away to show the primary internal components.

FIG. 2 is a perspective view of a head according to a preferred embodiment of the present invention.

FIG. 3 is a flowchart of a method of contouring a surface portion of the head of FIG. 2 in accordance with a preferred embodiment of the present invention.

FIG. 4 is a flowchart depicting a preferred embodiment of the rotate disc step of FIG. 3 in more detail.

FIG. 5 is a chart depicting the contour of a surface portion of a head before subjecting the surface portion to the contouring method of FIG. 3.

FIG. 6 is a chart depicting the contour of a surface portion of a head after subjecting the surface portion to the contouring method of FIG. 3.

Detailed Description

A disc drive **100** constructed in accordance with a preferred embodiment of the present invention is shown in FIG. **1**. The disc drive **100** includes a base **102** to which various components of the disc drive **100** are mounted. A top cover **104**, shown partially cut away, cooperates with the base **102** to form an internal, sealed environment for the disc drive in a conventional manner. The components include a spindle motor **106**, which rotates one or more discs **108** at a constant high speed. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates during a seek operation about a bearing shaft assembly **112** positioned adjacent the discs **108**. The actuator assembly **110** includes a plurality of actuator arms **114** which extend towards the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118**, which acts as an air bearing slider enabling the head **118** to fly in close proximity above the corresponding surface of the associated disc **108**.

During a seek operation, the track position of the heads **118** is controlled through the use of a voice coil motor **124**, which typically includes a coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets **128** which establish a magnetic field in which the coil **126** is immersed. The controlled application of current to the coil **126** causes magnetic interaction between the permanent magnets **128** and the coil **126** so that the coil **126** moves in accordance with the well-known Lorentz relationship. As the coil **126** moves, the actuator assembly **110** pivots about the bearing shaft assembly **112**, and the heads **118** are caused to move across the surfaces of the discs **108**.

The spindle motor **106** is typically de-energized when the disc drive **100** is not in use for extended periods of time. The heads **118** are moved over park zones **120** such as near the inner diameter of the discs **108** when the drive motor is de-energized. The heads **118** can be secured over the park zones **120** through the use of an actuator latch arrangement, which prevents inadvertent rotation of the actuator assembly **110** when the heads are parked. Park zones **120** preferably are textured to form bumps that prevent stiction between each park zone **120** and the

corresponding head **118** when the head **118** is in contact with the park zone **120**. Directed laser light preferably forms the bumps in the park zones **120**.

A flex assembly **130** provides the requisite electrical connection paths for the actuator assembly **110** while allowing pivotal movement of the actuator assembly **110** during operation. The flex assembly includes a printed circuit board **132** to which head wires (not shown) are connected; the head wires being routed along the actuator arms **114** and the flexures **116** to the heads **118**. The printed circuit board **132** typically includes circuitry for controlling the write currents applied to the heads **118** during a write operation and a preamplifier for amplifying read signals generated by the heads **118** during a read operation. The flex assembly terminates at a flex bracket **134** for communication through the base deck **102** to a disc drive printed circuit board (not shown) mounted to the bottom side of the disc drive **100**.

FIG. **2** depicts the underside **200** of a head **118** that faces a corresponding surface **201** of the disc **108** (see FIG. **1**). The head **118** shown in FIG. **2** is a conventional head design, but the scope of the invention includes other head designs. Orientation terms such as "under", "down", and "up" are used for convenience, but the head **118** can be oriented in many different ways so long as it is appropriately oriented relative to the corresponding disc surface **201** (see FIG. **1**). The head **118** is preferably comprised of conventional materials and formed according to known manufacturing methods.

The head **118** includes a body **202**, which may be any of various known shapes, but is shown in FIG. **2** as a rectangular block. The body **202** defines a leading edge **203** that is the first portion of the head **118** to encounter a particular section of the disc surface **201** as the disc **108** (see FIG. **1**) rotates beneath the head **118**. A trailing edge **204** of the body **202** faces opposite the leading edge **203**. A transducer riser **206** depends from the body **202** near the trailing edge **204**, and a read/write transducer **208** is mounted on the transducer riser **206** distal from the body **202.**

In one preferred embodiment, a generally U-shaped rail **214** depends from the body **202.** The rail **214** includes a base **216** near the leading edge **203** and arms **218** extending rearward from opposing sides of the base **216** so that the U-shaped rail **214** opens toward the transducer **208**. Leading contact pad risers **222** depend from opposite ends of the base **216** of the rail **214**. Leading contact pads **224** depend from the leading contact pad risers **222** toward the disc surface **201** (see FIG. **1**). Near the trailing ends of the arms **218**, trailing contact pad risers **226** depend from the rail **214**, and trailing contact pads **228** depend from the trailing contact pad risers **226**.

In the embodiment shown in FIGS. **1** and **2**, the leading contact pads **224** and the trailing contact pads **228** are at approximately the same height relative to the disc surface **201** when the head **118** is resting on the disc surface **201**. However, when the disc **108** rotates at such a speed that head **118** flies above the disc surface **201**, the leading edge **203** flies higher than the trailing edge **204**. Thus, during flight the trailing contact pads **228** are lower (i.e., closer to the disc surface **201**) than the leading contact pads **224**. Accordingly, if any part of the head **118** contacts the disc surface **201** during flight, it is likely that a downwardly facing surface portion **230** of one or more trailing contact pads **228** will contact surface **201**.

Of course, the surface portion **230** could be the entire downwardly facing surface of the contact pad **228** or only a portion of it. Furthermore, while a particular head configuration is shown and described above, the burnishing method described below will improve the performance of heads with other configurations. For example, a head **118** could have a different number of contact pads in the front or rear. Likewise, the leading contact pads **224** could extend downwardly far enough so that a surface portion of the leading contact pads **224** would be first to contact the disc surface during flight. Indeed, the head **118** could be configured so that some surface portion other than the features shown in FIG. **2** is first to contact the disc surface. Thus, embodiments of the present invention are not limited by the particular head configuration shown in FIG. **2**.

In operation, as a disc **108** rotates beneath the head **118**, the head **118** flies above the disc surface **201** a predetermined distance called a gap fly height. With the decreases in fly height, it is desirable to have the contours of the pad surface portions **230** be smooth and precisely fit to the corresponding disc surface **201** so that asperities in the pad surface portions **230** do not inadvertently contact the disc surface **201** during normal operation of the disc drive **100**. However, variations in the precise fit between each head **118** and disc **108** makes the prefabrication of a pad surface portion **230** that will be contoured to complement the corresponding disc surface **201** problematic. FIGS. **3** and **4** depict a preferred embodiment for contouring a surface portion of a head, such as surface portion **230**, so that it is smooth and complements the corresponding disc surface **201**.

Referring now to FIGS. **1-3**, in step **240** the actuator assembly **110** and the disc **108** are assembled in the disc drive **100** according to known manufacturing methods. Preferably as part of the known manufacturing methods, the surface portions **230** are lapped to provide a smooth surface and they are coated through masks in accordance with known methods. In step **242** the

head **118** is positioned over the park zone **120**. Preferably, the head **118** is then resting with the contact pads **224** and **228** contacting the disc surface **201**. In step **244** the disc is rotated while the head **118** is maintained substantially over the park zone **120**. During step **244**, the pad surface portions **230** are burnished by the interaction between the park zone **120** and the pad surface portions **230**. This burnishing includes contact between the park zone **120** and the pad surface portions **230**, but it does not necessarily include constant contact. In fact, intermittent contact may be more preferred than constant contact in some situations, such as where the rotating step **244** includes multiple starting and stopping sequences. The burnishing preferably contours the pad surface portions **230** so that they precisely fit with the complimenting surfaces of the park zone **120**, according to the specific static roll and pitch attitude of the slider, and thus they also precisely fit with the remainder of the corresponding disc surface **201**. When the surface portions **230** have been sufficiently burnished, the method is terminated at step **246**.

Computer-executable instructions for performing the method of FIG. **3** may be included in the disc drive or may be sent to the disc drive from an external source. In a preferred embodiment, disc drive **100** includes computer executable instructions that will automatically instruct the disc drive **100** to perform the method when it is first started (i.e., during a test or burn-in phase following manufacturing and prior to shipment of the drive).

Referring now to FIGS. **1-2** and **4**, a preferred embodiment of the rotating step **244** will be described in more detail. A start/stop sequence is repeated until a predetermined number of start/stop sequences have been performed. Each start/stop sequence includes starting the disc rotation at step **252**, preferably so that the head **118** takes off from the park zone **120**, and stopping the disc rotation at step **254**, preferably so that the head **118** lands once again in the park zone **120**. In step **256**, the method determines whether a predetermined number of start/stop sequences have been performed. If the predetermined number of sequences has not been performed, then the method returns to step **252** and another start/stop sequence is performed. If the predetermined number of start/stop sequences has been performed, indicating that the surface portion **230** of the head **118** has been sufficiently burnished, then the method is terminated at step **258**. The number of sequences should be chosen so that the surface portion **230** is sufficiently burnished to provide a smooth surface that complements the corresponding disc surface **201** without producing undue wear of the surface portion **230**. From initial testing, it appears that from about 100 to about 500 start/stop sequences provides sufficient burnishing.

Notably, the method of FIGS. **3-4** is preferably performed using only existing disc drive components and does not require a separate manufacturing step. Thus, it is less expensive to perform than a method of burnishing the head **118** before mounting it in the disc drive **100**. Additionally, the exact orientation of the head **118** relative to the disc drive **100** can change from one drive to another even if the drives were designed to be the same. Thus, it is believed that performing the burnishing method on the disc **108** itself with the head **118** already mounted in the disc drive accounts for the head's unique orientation by contouring the head to complement the corresponding disc surface. Although the burnishing is performed only in the park zone **120**, the orientation of the head **118** with respect to the park zone **120** will be similar to its orientation with respect to the remainder of the disc surface **201**. In alternative embodiments, two or more textured landing zones can be provided at various radial positions, such as the inner and outer diameter, for burnishing the head **118** at multiple disc locations. The smoothing and contouring that result from the burnishing method help to prevent contact between the head **118** and the disc **108** during subsequent normal operation of the disc drive **100**.

To demonstrate the results of the method of FIGS. **3-4** on disc drive performance, a new head **118** was tested for 100 cycles. Each cycle included flying the head on a track (at a constant disc radius) for ten seconds and sweeping the head between the inner and outer radius of the disc **108** for twenty seconds. The new head **118** was not burnished before beginning the test. In the first 100 cycles, a force transducer indicated that the head had contacted the disc surface several times. After 100 cycles, the head was burnished as described above with reference to FIG. **4** for 500 start/stop sequences. The test was then resumed for more than five days (30000 cycles) without any detected contact between the disc and the head. Accordingly, the method described above with reference to FIGS. **3** and **4** significantly decreases the number of contacts between the head and the disc during normal disc operation, thereby increasing the reliability and durability of the disc drive.

FIGS. **5** and **6** depict the surface contour of a surface portion **230** before and after burnishing in accordance with the present invention and demonstrate the decreased roughness of the head surface. In both figures, the vertical axis is a measure of the vertical position (normal to the surface portion **230** in the direction of arrow **300** in FIG. **2**) of the surface portion **230** measured in nanometers (nm) and the horizontal axis is a measure of the horizontal position (along the surface portion **230** in the direction of arrow **301** in FIG. **2**) of the surface portion **230** measured in micrometers (μm). The scale of FIGS. **5** and **6** is substantially the same.

To aid in analyzing the difference between the roughness of the surface in FIG. **5** and that of FIG. **6**, adjacent upper and lower points were measured. Referring to FIG. **5**, the horizontal distance between a first upper point **302** and an adjacent first lower point **304** of the surface portion **230** before burnishing was 234.38 nm while the vertical distance between the two points **302, 304** was 3.453 nm, yielding a surface angle of 0.844 degree relative to the horizontal axis. The surface between the first upper point **302** and the first lower point **304** appears to be the steepest incline of the surface portion **230** before burnishing. The horizontal distance between a second upper point **306** and an adjacent second lower point **308** of the surface portion **230** before burnishing was 546.88 nm while a vertical distance between the two points **306, 308** was 0.960 nm, yielding a surface angle of 0.101 degree relative to the horizontal axis.

The head was then burnished as described above in FIG. **4** for 250 start/stop sequences. Referring to FIG. **6**, the horizontal distance between an upper point **312** and an adjacent lower point **314** of the surface portion **230** after burnishing was 234.38 nm while a vertical distance between the two points **312, 314** was 0.272 nm yielding a surface angle of 0.066 degree relative to the horizontal axis. The surface between the upper point **312** and the lower point **314** appears to be the steepest substantial incline of the surface portion **230** after burnishing. Therefore, the steepest incline angle before burnishing (0.844 degree) was more than ten times the steepest incline angle after burnishing (0.066 degree). This leads to the conclusion that the surface portion **230** was significantly smoother after burnishing than it was before and that asperities in the surface portion **230** were removed by the burnishing method. This conclusion was verified by calculating the roughness, Ra, of the surface portion **230** before and after burnishing. Ra is a value representing the average roughness across a line of the surface. A greater value of Ra represents a rougher surface. The roughness of the surface portion **230** before burnishing was 0.58 nm, while the roughness after burnishing was 0.37 nm.

In an alternative embodiment, the rotating step **244** of FIG. **3** is accomplished by continuously rotating the disc **108** with the head **118** remaining in the park zone **120**. In this embodiment, rather than performing numerous start/stop sequences, the disc **108** is rotated at a predetermined speed for a selected time. Preferably in this embodiment, the disc **108** is rotated for between five and thirty minutes. The speed is preferably chosen to maximize the burnishing effect of the park zone **120** on the head **118**. Preferably, the speed is below the normal operating speed of the disc drive **100**, and even more preferably below the full take off speed of the disc drive **100** so that the head **118** remains in constant contact with the park zone **120**. However, the

speed may be above the take off speed and it may even be at the normal operating speed so long as the head **118** flies low enough to contact the bumps formed in the park zone **120**.

In summary, an embodiment of the present invention is a method of contouring a surface portion (such as **230**) of a head (such as **118**) for a disc drive (such as **100**) that includes a disc (such as **108**) rotatably mounted on a base (such as **102**). The method includes positioning (such as **242**) the head over a park zone (such as **120**) of the disc (such as **108**) and rotating (such as **244**) the disc (such as **108**) for a selected time to burnish the head against the park zone of the disc while maintaining the head positioned substantially over the park zone.

The park zone may comprise a textured surface, which preferably includes bumps that interact with the surface portion of the head. The rotating step may include rotating the disc at a fixed rotational speed for the selected time. The fixed rotational speed may be less than an operating rotational speed of the disc, and is preferably less than a full take off speed of the drive. The rotating step preferably includes rotating the disc for a period of time of from about five minutes to about thirty minutes. Alternatively, the rotating step may include plural sequences of starting and stopping the disc. In a preferred embodiment, the rotating step includes from about 100 to about 500 starting and stopping sequences.

Alternatively, an embodiment of the present invention may be summarized as a disc drive (such as **100**) including a disc (such as **108**) rotatably mounted on a spindle motor (such as **106**) mounted on a base (such as **102**) and an actuator assembly (such as **110**) mounted adjacent the disc, the actuator assembly having an actuator arm (such as **114**) including a distal end supporting a head (such as **118**) over a surface (such as **201**) of the disc. The head includes a head surface portion (such as **230**) facing the disc surface, wherein the head surface portion has been contoured by positioning the head over a park zone (such as **120**) on the disc and maintaining the head positioned substantially over the park zone of the disc while rotating the disc for a selected tiem so as to burnish the head surface portion. In a preferred embodiment, the head surface portion preferably has a roughness of less than about 0.5 nanometers.

An embodiment of the present invention may also be summarized as a method of contouring the surface portion of the head for the disc drive that includes the disc rotatably mounted on the base. The method includes positioning the head over the park zone of the disc and contouring the head surface portion to reduce contact between the head and the disc during operation of the disc drive. The step for contouring may include rotating the disc at a fixed

rotational speed for the selected time. Alternatively, the step for contouring may include plural sequences of starting (such as **252**) and stopping (such as **254**) rotation of the disc.

It will be clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. For example, the speed of the disc rotation during burnishing could be sequentially increased and decreased without completely stopping the disc rotation. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.